Elaboration of technology for manufacturing aluminum-based metal-matrix composite material strengthened with hollow ceramic microspheres for using thereof in underwater equipment

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Abstract. This paper deals with the study of capabilities for strengthening an aluminum alloy with hollow ceramic microspheres. The results of the microstructural analysis and the investigation of strength properties for the aluminum-silicon alloying system are described herein. For comparison Experiments have been carried out for comparison both with classical microspheres and with chromium- and chromium-carbide-coated microspheres to increase the melt adhesion to a microsphere

1 Introduction

The active development of fundamentally new structural materials is currently in great progress. It enables to achieve the qualitative improvement in technical characteristics of machinery and mechanisms. To a large extent metal-matrix composite materials (MMC) shall meet such demands as the purposeful regulation of the composition and the improvement of their manufacturing methods allows to reach quite a new level of performance properties [1-3]. A growing interest in aluminum alloys-based MMC is determined by their improved mechanical and service properties combined with the low density. It should be noted that alongside with the size and degree of saturation the adhesion of the matrix with reinforcing particles has a decisive effect on the mechanical and service properties [4-7]. Furthermore, quite a significant reserve is available for the further improvement of dispersed- filled MMC properties due to developing various manufacturing technologies [8-12].

As one of the possible lines for their application there may be the MMC use for a main body of hard diving suits (Atmospheric Diving Suits).

At present a special type of material such as foam aluminum is also applied in machinery; porous aluminum may have the porosity up to 80% with the pore size up to 5 mm and the density of 300 kg/m³. The strength and plastic properties of the foam

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essentially depend on its density [11–13]. However, this material has low mechanical properties and some significant constraints for producing complex-shaped components.

In general, the mechanical properties of such foam materials are conditioned by their three-dimensional isotropic structure and are mainly determined by the behavior of individual structural elements - base-alloy jumpers and the material compression occurs in four stages. At the first stage the deformation of the weakest elements of the frame and the edge non-homogeneities occur under low loads, at the second stage the elastic deformation takes place and at the third stage the said jumpers lose the stability, plastic deformations develop and the compression diagram passes to a flat section, the so-called compression plateau. This process has a cyclic chain character: the loss of the stability by one of the jumpers causes the development of the deformation in adjacent ones and further throughout the entire layer; material layers gradually collapse to the compactification limit, when the pores are finally closed and the deformed material begins to acquire the properties of a compact one. At the fourth stage the stress in the material again increases and it gradually approaches the compact material.

2 Statement of the Problem

In paper [14] a technology was proposed for producing a low-density aluminum-based material by introducing into melt hollow ceramic microspheres, including those coated with chromium and chromium carbide to increase the melt adhesion to a microsphere. For these purposes the chemical gas-phase precipitation was used by the MOCVD method (Metal organic chemical vapor deposition [15 - 20]).

3 Experiment Procedure

In the course of the work there were studied the mechanical properties of aluminum alloy A6 specimens (99.6% Al, 0.25% Fe, 0.2% Si), AK9ч (Si 8-10.5%, Mn 0.-0.5%, Cu 0-0.3%, Mg 0.17-0.3%, Zn 0-0.3%), AK12ч (Si 10-13%, Mn 0-0.4%, Cu 0-0.2%) saturated with spheres produced under various technologies.

Hollow ceramic microspheres were pre-pressed under the pressure up to 200 atm. After that sieving was carried out and only those microspheres were used which had passed the test.

Aluminum alloy was melted and brought to the temperature of 750°C in an induction crucible furnace, samples of spheres of various volumes were preheated to a temperature of at least 500°C within an hour in a muffle furnace. Spheres were introduced into melt with a mixing device. Such obtained alloy was cast out into split molds. After that T6 heat treatment was performed for AK9ch alloy, T5 for AK12ch alloy and A6 alloy was tested without heat treatment. Under similar conditions the casting and heat treatment of alloy samples not saturated with microspheres (base alloys) were performed. The heat treatment of base alloys was carried out simultaneously with microsphere-saturated alloys.

4 Outcomes of Experiments

Examples of microstructure of samples saturated with spheres are shown in Figs. 1–3. The tensile strength dependence on the degree of saturation with spheres is shown in Figs 4 - 6.

Fig. 1. Aluminosilicate microspheres before (left) metallization and after (right) pyrolytic chromium coating

Fig. 2. Coated microsphere surface skew

Fig. 3. Microsphere destroyed during splice preparation

Fig. 4. Dependence of ultimate strength of A6 alloy on saturation degree

Fig. 5. Dependence of ultimate strength of AK12 T2 alloy on saturation degree

Fig. 6. Dependence of ultimate strength of AK9 T6 alloy on saturation degree

In all cases alloys saturated with particles showed an increase in the tensile strength. A more significant increase in the tensile strength for alloy A6 is conditioned by the "low base", since the strength of the base alloy A6 is about 80 MPa.

5 Conclusions

The described method of producing alumomatrix MMC saturated with spherical ceramic particles enables to obtain a material with improved mechanical properties as compared to basic aluminum. Moreover, due to hollow microspheres a smaller specific weight and the mass of a component are achieved.

In this case the tensile strength of a material saturated with metalized microspheres is higher relatively to the tensile strength of a material saturated with classical spheres.

The described method of producing aluminum-matrix MMC saturated with spherical ceramic particles enables to obtain a material with improved mechanical properties as compared to basic aluminum. Moreover, due to hollow microspheres a smaller specific weight and the mass of a component are achieved, thus, allowing to more fully implementing MMC potentialities.

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